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Simulation of the dynamical history of the northwestern Greenland ice sheet with a nested model for interpretation of the NEEM ice core record

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Accurate interpretation of proxy climatic records from deep ice cores requires the separation of the climatic signal from non-climatic components (biases). Non-climatic biases arise from elevation changes of the ice sheet, advection of higher upstream ice, and from latitudinal contrasts in isotopical composition of the ice. This separation requires detailed mathematical modeling of the ice-flow history around the drill site.

We employ a 3-D nested ice-dynamic model for the reconstruction of the ice flow in the area between the NEEM and the NGRIP drill sites in northwestern Greenland during the last two glacial-interglacial cycles. The model consists of a low-resolution time-dependent shallow-ice-approximation model responsible for the simulation of the ice-sheet evolution and of an embedded diagnostic LMLa-type higher-order model on a 400×400 km domain. The modeled present-day surface velocity field is in good agreement with satellite and GPS measurements.

The ice chronology and non-climatic biases are calculated by means of a Lagrangian backtracing procedure. An attempt to reproduce the correct depth of the δ18O maximum in the NEEM ice core gives a mismatch between the modeled chronology and the GICC05/ss09 chronology below $\sim$1200 m depth. Conversely, the GICC05/ss09 chronology locates the δ18O maximum $\sim$150 higher than its actual position in the core. This discrepancy can be explained by stratigraphical disturbances in the lower part of the Greenland ice sheet between NEEM and NGRIP drill sites as revealed by radio echo-sounding. For this reason, we limit model-based estimates of the ice chronology and non-climatic biases for the NEEM ice core to $\sim$87% of relative depth. In terms of time it means that prior to ca. 108 kyr BP the non-climatic biases can only be estimated approximately. Our estimate shows that the measured contrast between the present and the Eemian δ18O must be increased by about 1.5‰.